



(11)

EP 3 184 745 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
28.06.2017 Bulletin 2017/26

(51) Int Cl.:
F01D 5/18 (2006.01)

(21) Application number: **16205162.7**

(22) Date of filing: **19.12.2016**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD

(72) Inventors:
• **WEBER, David Wayne**
Greenville, SC South Carolina 29615 (US)
• **CIRAY, Mehmet Suleyman**
Greenville, SC South Carolina 29615 (US)
• **PERRY, II, Jacob Charles**
Greenville, SC South Carolina 29615 (US)

(30) Priority: **21.12.2015 US 201514977124**

(74) Representative: **Lee, Brenda et al**
GE International Inc.
Global Patent Operation - Europe
The Ark
201 Talgarth Road
Hammersmith
London W6 8BJ (GB)

(71) Applicant: **General Electric Company**
Schenectady, NY 12345 (US)

(54) **COOLING CIRCUIT FOR MULTI-WALL BLADE**

(57) A turbine blade cooling system according to an embodiment includes: a first turn 60, 160 for redirecting a first flow of gas flowing through a first channel 28 of a turbine blade 6 into a central plenum 44 of the turbine blade 6; and a second turn 70, 170 for redirecting a sec-

ond flow of gas flowing through a second channel 38 of the turbine blade 6 into the central plenum 44; wherein the first turn 60, 160 is offset from the second turn 70, 170 to reduce impingement of the first flow of gas and the second flow of gas in the central plenum 44.

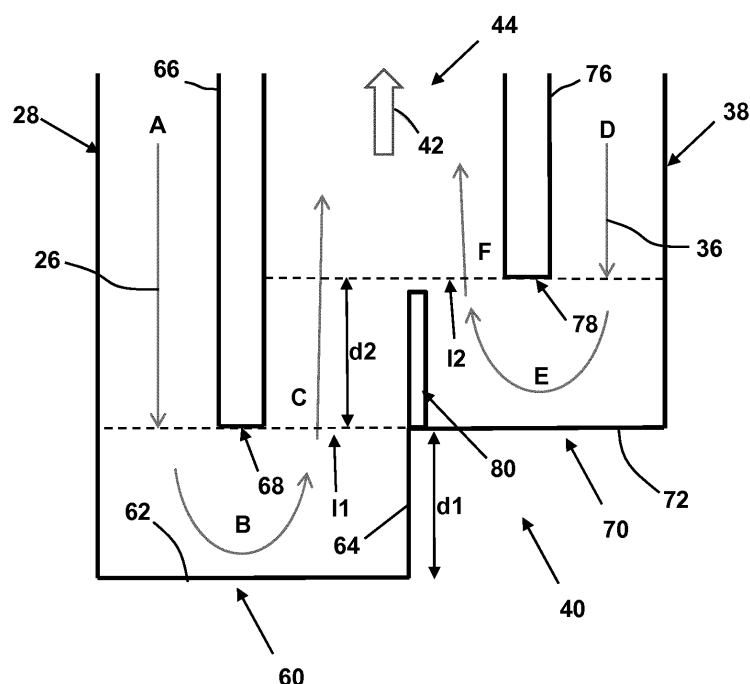


FIG. 3

EP 3 184 745 A1

Description

[0001] The disclosure relates generally to turbine systems, and more particularly, to reducing pressure loss in a multi-wall turbine blade cooling circuit.

[0002] Gas turbine systems are one example of turbomachines widely utilized in fields such as power generation. A conventional gas turbine system includes a compressor section, a combustor section, and a turbine section. During operation of the gas turbine system, various components in the system, such as turbine blades, are subjected to high temperature flows, which can cause the components to fail. Since higher temperature flows generally result in increased performance, efficiency, and power output of the gas turbine system, it is advantageous to cool the components that are subjected to high temperature flows to allow the gas turbine system to operate at increased temperatures.

[0003] Turbine blades of a gas turbine system typically contain an intricate maze of internal cooling channels. The cooling channels receive air from the compressor of the gas turbine system and pass the air through the internal cooling channels to cool the turbine blades. The feed pressure of the air passed through the cooling channels is generally at a premium, since the air is bled off of the compressor. To this extent, it is useful to provide cooling channels that reduce non-recoverable pressure loss; as pressure losses increase, a higher feed pressure is required to maintain an adequate gas-path pressure margin (back-flow margin). Higher feed pressures result in higher leakages in the secondary flow circuits (e.g., in rotors) and higher feed temperatures.

[0004] A first aspect of the disclosure provides a turbine blade cooling system, including: a first turn for redirecting a first flow of gas flowing through a first channel of a turbine blade into a central plenum of the turbine blade; and a second turn for redirecting a second flow of gas flowing through a second channel of the turbine blade into the central plenum; wherein the first turn is offset from the second turn to reduce impingement of the first flow of gas and the second flow of gas in the central plenum. second aspect of the disclosure provides a turbine bucket, including: a shank; a blade coupled to the shank; and a cooling system, the cooling system including: a first turn for redirecting a first flow of gas flowing through a first channel of the blade into a central plenum of the blade; a second turn for redirecting a second flow of gas flowing through a second channel of the blade into the central plenum of the blade; wherein the first turn is offset from the second turn to reduce impingement of the first flow of gas and the second flow of gas in the central plenum of the blade, the reduced impingement decreasing pressure loss in the central plenum of the blade.

[0005] A third aspect of the disclosure provides a turbine bucket, comprising: a shank; a multi-wall blade coupled to the shank; and a cooling system, the cooling system including: a first turn for redirecting a first flow of gas flowing through a first channel into a central plenum of

the blade; a second turn for redirecting a second flow of gas flowing through a second channel into the central plenum of the blade, the first flow of gas and the second flow of gas combining in the central plenum; wherein the first turn is angularly offset from the second turn to reduce impingement of the first flow of gas and the second flow of gas in the central plenum of the blade, the reduced impingement decreasing pressure loss in the central plenum.

[0006] The illustrative aspects of the present disclosure solve the problems herein described and/or other problems not discussed.

[0007] Various features of this disclosure will be more readily understood from the following detailed description of the various aspects of the disclosure taken in conjunction with the accompanying drawing that depicts various embodiments of the disclosure.

FIG. 1 shows a perspective view of a turbine bucket including a blade, according to embodiments.

FIG. 2 is a partial cross-sectional view of the blade of FIG. 1, taken along line 2--2 in FIG. 1, according to embodiments.

FIG. 3 depicts a pressure loss reducing structure with opposing feeds, according to embodiments.

FIG. 4 is a partial cross-sectional view of the blade of FIG. 1 depicting a pressure loss reducing structure with opposing feeds, according to embodiments.

FIG. 5 depicts a pressure loss reducing structure with angled feeds, according to embodiments.

FIG. 6 is a partial cross-sectional view of the blade of FIG. 1 depicting a pressure loss reducing structure with angled feeds, according to embodiments.

[0008] It is noted that the drawing of the disclosure is not to scale. The drawing is intended to depict only typical aspects of the disclosure, and therefore should not be considered as limiting the scope of the disclosure. In the drawing, like numbering represents like elements between the drawings.

[0009] As indicated above, the disclosure relates generally to turbine systems, and more particularly, to reducing pressure loss in a multi-wall turbine blade cooling circuit.

[0010] Turning to FIG. 1, a perspective view of a turbine bucket 2 is shown. The turbine bucket 2 includes a shank 4 and a blade 6 (e.g., a multi-wall blade) coupled to and extending radially outward from the shank 4. The blade 6 includes a pressure side 8 and an opposed suction side 10. The blade 6 further includes a leading edge 12 between the pressure side 8 and the suction side 10, as well as a trailing edge 14 between the pressure side 8 and the suction side 10 on a side opposing the leading

edge 12.

[0011] The shank 4 and blade 6 may each be formed of one or more metals (e.g., steel, alloys of steel, etc.) and can be formed (e.g., cast, forged or otherwise machined) according to conventional approaches. The shank 4 and blade 6 may be integrally formed (e.g., cast, forged, three-dimensionally printed, etc.), or may be formed as separate components which are subsequently joined (e.g., via welding, brazing, bonding or other coupling mechanism).

[0012] FIG. 2 is a partial cross-sectional view of the blade 6 taken along line 2--2 of FIG. 1, depicting a cooling arrangement 16 including a plurality of cooling circuits, according to embodiments. In this example, the cooling arrangement 16 includes an internal 2-pass serpentine suction side (SS) cooling circuit 18 on the suction side 10 of the blade 6 as well as an internal 2-pass serpentine pressure side (PS) cooling circuit 20 on the pressure side 8 of the blade 6. Although described in terms of a 2-pass serpentine cooling circuit, it should be apparent to those skilled in the art that the pressure loss reducing structures of the present disclosure (described below) may be used in conjunction with other types of serpentine (e.g., 3-pass, 4-pass, etc.) and/or non-serpentine cooling circuits in which "spent" cooling air from a plurality of flow channels is collected for redistribution to other areas of the blade 6, shank 4, and/or other portions of the bucket 2 for cooling purposes. Further, the pressure loss reducing structures may be used in other sections of the blade 6, shank 4, and/or other portions of the bucket 2 where there is a need for gathering a plurality of gas flows into a single gas flow for redistribution.

[0013] The SS cooling circuit 18 includes a feed channel 22 for directing a flow of cooling gas 24 (e.g., air) radially outward toward a tip area 48 (FIG. 1) of the blade 6 along the suction side 10 of the blade 6. In FIG. 2, the flow of cooling gas 24 is depicted as flowing out of the page. After passing through a turn (not shown), a flow of "spent" cooling gas 26 is directed back towards the shank 4 of the blade 6 through a return channel 28. In FIG. 2, the flow of cooling gas 26 is depicted as flowing into the page.

[0014] The PS cooling circuit 20 includes a feed channel 32 for directing a flow of cooling gas 34 (e.g., air) radially outward toward the tip area 48 (FIG. 1) of the blade 6 along the pressure side 8 of the blade 6. After passing through a turn (not shown), a flow of "spent" cooling gas 36 is directed back towards the shank 4 of the blade 6 through a return channel 38. In FIG. 2, the flow of cooling gas 34 is depicted as flowing out of the page, while the flow of cooling gas 36 is depicted as flowing into the page.

[0015] According to embodiments, referring to FIGS. 3 and 5, together with FIG. 2, a pressure loss reducing structure 40 (FIG. 3), 50 (FIG. 5) is provided for combining the flow of cooling gas 26 flowing through the return channel 28 of the SS cooling circuit 18 with the flow of cooling gas 36 flowing through the return channel 38 of the PS

cooling circuit 20, to form a single, combined flow of cooling gas 42 within a central plenum 44. Advantageously, this is achieved with reduced pressure loss by preventing impingement of the flows of cooling gas 26, 36 as the flows enter the central plenum 44. The pressure loss reducing structure 40, 50 is configured to offset the flows of cooling gas 26, 36 either positionally (FIG. 3) or angularly (FIG. 5) such that the flows of cooling gas 26, 36 do not impinge on one another in the center plenum 44.

[0016] In the blade 6, the flow of cooling gas 42 passes radially outward through the central plenum 44 (out of the page in FIG. 2). From the center plenum 44, the flow of cooling gas 42 may be redistributed, for example, to a leading edge cavity 46 (FIG. 1) located in the leading edge 12 of the blade 6 to provide impingement cooling. Alternatively, or in addition, the flow of cooling gas 42 may be redistributed to a tip area 48 (FIG. 1) of the blade 6. The flow of cooling gas 42 may also be provided to other locations within the blade 6, shank 4, and/or other portions of the bucket 2 to provide convention cooling. Still further, the flow of cooling gas 42 may be used to provide film cooling of the exterior surfaces of the blade 6. Depending on the location of the pressure loss reducing structure 40, 50 in the blade 6, the flow of cooling gas 42 may be also be redistributed, for example, to cooling channels/circuits at the trailing edge 14 of the blade 6. Any number of pressure loss reducing structures 40, 50 may be employed within the blade 6.

[0017] A first embodiment of a pressure loss reducing structure 40 including opposing feeds is depicted in FIG. 3. As shown in FIG. 3, the flow of cooling gas 26 flowing through the return channel 28 of the SS cooling circuit 18 flows through the return channel 28 in a first direction (arrow A) to a first turn 60 of the pressure loss reducing structure 40. At the first turn 60, the flow of cooling gas 26 is redirected (arrow B) by an end wall 62 and side wall 64 of the first turn 60. The redirected flow of cooling gas 26 subsequently flows toward and into (arrow C) the center plenum 44, forming a portion of the flow of cooling gas 42. The return channel 28 and the center plenum 44 are separated by a rib 66. As shown in FIG. 3, the flow of cooling gas 26 flows around an end section 68 of the rib 66.

[0018] Also depicted in FIG. 3 is a second turn 70 of the pressure loss reducing structure 40. The flow of cooling gas 36 flowing through the return channel 38 of the PS cooling circuit 20 flows through the return channel 38 in a first direction (arrow D) to the second turn 70 of the pressure loss reducing structure 40. At the second turn 70, the flow of cooling gas 36 is redirected (arrow E) by an end wall 72 of the second turn 70. The redirected flow of cooling gas 36 subsequently flows toward and into (arrow F) the center plenum 44, forming another portion of the flow of cooling gas 42. The return channel 38 and the center plenum 44 are separated by a rib 76. The flow of cooling gas 36 flows around an end section 78 of the rib 76.

[0019] As shown in FIG. 3, the end walls 62, 72 of the

first and second turns 60, 70 are positionally offset (e.g., radially along a length of the blade 6) from one another by a distance d1. According to embodiments, D1 may be greater than or equal to a height of the first turn 60. Further, the end sections 68, 78 of the ribs 66, 76, as well as the inlets I1, I2 into the central plenum 44, are positionally (e.g., vertically) offset from one another by a distance d2. Depending on the specific implementation of the pressure loss reducing structure 40, d1 and d2 may be substantially equal. In addition, the end section 68 of rib 66 may be coplanar with the end wall 72 of the second turn 70. A rib 80 may be positioned between the first and second turns 60, 70 to help guide and align the redirected flows of cooling gas 26, 36 as the flows enter the center plenum 44. Advantageously, the redirected flows of cooling gas 26, 36 flow into the center plenum 44 with reduced impingement and reduced associated pressure loss.

[0020] FIG. 4 is a partial cross-sectional view of the blade of FIG. 1 depicting the pressure loss reducing structure 40. As shown, the flow of cooling gas 26 flows through the return channel 28 in a first direction (into the page in FIG. 4) to a first turn 60 (FIG. 3) of the pressure loss reducing structure 40. At the first turn 60, the flow of cooling gas 26 is redirected by the end wall 62 and side wall 64 (FIG. 3) of the first turn 60. The redirected flow of cooling gas 26 subsequently flows in a second direction (out of the page in FIG. 4) into the center plenum 44, forming a portion of the flow of cooling gas 42. The return channel 28 and the center plenum 44 are separated by the rib 66.

[0021] The flow of cooling gas 36 flows through the return channel 38 in a first direction (into the page in FIG. 4) to the second turn 70 (FIG. 3) of the pressure loss reducing structure 40. At the second turn 70, the flow of cooling gas 36 is redirected by an end wall 72 of the second turn 70. The redirected flow of cooling gas 36 subsequently flows in a second direction (out of the page in FIG. 4) into the center plenum 44, forming another portion of the flow of cooling gas 42. The return channel 38 and the center plenum 44 are separated by the rib 76. The end walls 62, 72 of the first and second turns 60, 70 are positionally (e.g., vertically) offset from one another.

[0022] An embodiment of a pressure loss reducing structure 50 including angled feeds is depicted in FIG. 5 together with FIG. 6. As shown, the flow of cooling gas 26 flows through the return channel 28 in a first direction (arrow G) to the first turn 160 of the pressure loss reducing structure 50. At the first turn 160, the flow of cooling gas 26 is redirected (arrow H) by an end wall 162 of the first turn 160 and a rib 180. The redirected flow of cooling gas 26 flows (arrow I) in a swirling manner toward and into the center plenum 44, forming a portion of the flow of cooling gas 42. The return channel 28 and the center plenum 44 are separated by a rib 166. The flow of cooling gas 26 flows around an end section 168 of the rib 166.

[0023] Also depicted in FIG. 5 together with FIG. 6 is the second turn 170 of the pressure loss reducing structure 50. The flow of cooling gas 36 flows through the

return channel 38 in a first direction (arrow J) to the second turn 170 of the pressure loss reducing structure 50. At the second turn 170, the flow of cooling gas 36 is redirected (arrow K) by an end wall 172 of the second turn 70 and the rib 180. The redirected flow of cooling gas 36 subsequently flows (arrow L) in a swirling manner toward and into the center plenum 44, forming another portion of the flow of cooling gas 42. The swirling also acts to reduce pressure losses as the flows of cooling gas 26, 36 combine to form the flow of cooling gas 42. The return channel 38 and the center plenum 44 are separated by a rib 176. The flow of cooling gas 36 flows around an end section 178 of the rib 176.

[0024] Unlike the pressure loss reducing structure 40 shown in FIG. 3, the end walls 162, 172 of the first and second turns 160, 170 illustrated in FIG. 5 are not positionally (e.g., vertically) offset from one another in the pressure loss reducing structure 50. Rather, the end walls 162, 172 of first and second turns 160, 170 are substantially coplanar. In this embodiment, the rib 180 and the inlets I11 and I12 into the central plenum 44 are configured to angle and swirl the flows of cooling gas 26, 36 away from each other (e.g., in different directions), reducing flow impingement and reducing associated pressure loss. In embodiments, as depicted in FIG. 5, the rib 180 may be disposed at an angle α of sufficient to offset the opposing flows of cooling gas 26, 36. The flows of cooling gas 26, 36 pass into and through the central plenum 44 and combine to form the flow of cooling gas 42.

[0025] By preventing impingement of the flows of cooling gas 26, 36 as the flows enter the central plenum 44, pressure loss is reduced when using the pressure loss reducing structure 40, 50. Thus, a lower feed pressure is required to maintain an adequate gas-path pressure margin (back-flow margin). Further, lower feed pressures result in lower leakages in the secondary flow circuits (e.g., in rotors) and lower feed temperatures.

[0026] In various embodiments, components described as being "coupled" to one another can be joined along one or more interfaces. In some embodiments, these interfaces can include junctions between distinct components, and in other cases, these interfaces can include a solidly and/or integrally formed interconnection. That is, in some cases, components that are "coupled" to one another can be simultaneously formed to define a single continuous member. However, in other embodiments, these coupled components can be formed as separate members and be subsequently joined through known processes (e.g., fastening, ultrasonic welding, bonding).

[0027] When an element or layer is referred to as being "on", "engaged to", "connected to" or "coupled to" another element, it may be directly on, engaged, connected or coupled to the other element, or intervening elements may be present. In contrast, when an element is referred to as being "directly on", "directly engaged to", "directly connected to" or "directly coupled to" another element, there may be no intervening elements or layers present.

Other words used to describe the relationship between elements should be interpreted in a like fashion (e.g., "between" versus "directly between," "adjacent" versus "directly adjacent," etc.). As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

[0028] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the disclosure. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof

[0029] This written description uses examples to disclose the invention, including the preferred mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

[0030] Various aspects and embodiments of the present invention are defined by the following numbered clauses:

1. A turbine blade cooling system, comprising:

a first turn for redirecting a first flow of gas flowing through a first channel of a turbine blade into a central plenum of the turbine blade; and
a second turn for redirecting a second flow of gas flowing through a second channel of the turbine blade into the central plenum;

wherein the first turn is offset from the second turn to reduce impingement of the first flow of gas and the second flow of gas in the central plenum.

2. The turbine blade cooling system according to clause 1, wherein the turbine blade comprises a multi-wall turbine blade.

3. The turbine blade cooling system according to any preceding clause, wherein the reduced impingement decreases pressure loss in the central plenum.

4. The turbine blade cooling system according to any preceding clause, wherein the first turn includes an

end wall and the second turn includes an end wall, and wherein the end wall of the first turn is offset from the end wall of the second turn.

5. The turbine blade cooling system according to any preceding clause, wherein the offset comprises a positional offset.

6. The turbine blade cooling system according to any preceding clause, wherein the first turn further includes a side wall having a length equal to the positional offset.

7. The turbine blade cooling system according to any preceding clause, further comprising a rib disposed between the first turn and the second turn.

8. The turbine blade cooling system according to any preceding clause, wherein the first channel extends along a suction side of the blade, and wherein the second channel extends along a pressure side of the blade.

9. The turbine blade cooling system according to any preceding clause, wherein the offset comprises an angular offset.

10. The turbine blade cooling system according to any preceding clause, further comprising a rib disposed between the first turn and the second turn, wherein the rib directs the first flow of gas in a first direction into the central plenum, and wherein the rib directs the second flow of gas in a second, different direction into the central plenum.

11. The turbine blade cooling system according to any preceding clause, wherein the rib is positioned at an angle relative to the first turn and the second turn.

12. The turbine blade cooling system according to any preceding clause, wherein the first turn includes an end wall and the second turn includes an end wall, and wherein the end wall of the first turn is substantially coplanar with the end wall of the second turn.

13. A turbine bucket, comprising:

a shank;
a blade coupled to the shank; and
a cooling system, the cooling system including

a first turn for redirecting a first flow of gas flowing through a first channel of the blade into a central plenum of the blade;
a second turn for redirecting a second flow of gas flowing through a second channel of

the blade into the central plenum of the blade;

wherein the first turn is offset from the second turn to reduce impingement of the first flow of gas and the second flow of gas in the central plenum of the blade, the reduced impingement decreasing pressure loss in the central plenum of the blade.

14. The turbine bucket according to any preceding clause, wherein the turbine blade comprises a multi-wall turbine blade.

15. The turbine bucket according to any preceding clause, wherein the first turn includes an end wall and a side wall, wherein the second turn includes an end wall, and wherein the end wall of the first turn is positionally offset from the end wall of the second turn by a distance equal to a length of the side wall of the first turn.

16. The turbine bucket according to any preceding clause, wherein the first channel extends along a suction side of the blade, and wherein the second channel extends along a pressure side of the blade.

17. A turbine bucket, comprising:

a shank;
a multi-wall blade coupled to the shank; and
a cooling system, the cooling system including:

a first turn for redirecting a first flow of gas flowing through a first channel into a central plenum of the blade;
a second turn for redirecting a second flow of gas flowing through a second channel into the central plenum of the blade, the first flow of gas and the second flow of gas combining in the central plenum;

wherein the first turn is angularly offset from the second turn to reduce impingement of the first flow of gas and the second flow of gas in the central plenum of the blade, the reduced impingement decreasing pressure loss in the central plenum.

18. The turbine bucket according to any preceding clause, wherein the turbine blade further includes a rib disposed between the first turn and the second turn, wherein the rib directs the first flow of gas in a first direction into the central plenum, and wherein the rib directs the second flow of gas in a second, different direction into the central plenum.

19. The turbine bucket according to any preceding

clause, wherein the first turn includes an end wall and the second turn including an end wall, and wherein the end wall of the first turn is substantially coplanar with the end wall of the second turn.

20. The turbine bucket according to any preceding clause, wherein the combined flow of gas in the central plenum is provided by the cooling system to other areas of the blade or shank for cooling.

Claims

1. A turbine blade cooling system, comprising:

a first turn (60, 160) for redirecting a first flow of gas flowing through a first channel (28) of a turbine blade (6) into a central plenum (44) of the turbine blade (6); and

a second turn (70, 170) for redirecting a second flow of gas flowing through a second channel (38) of the turbine blade (6) into the central plenum (44);

wherein the first turn (60, 160) is offset from the second turn (70, 170) to reduce impingement of the first flow of gas and the second flow of gas in the central plenum (44).

2. The turbine blade cooling system according to claim 1, wherein the turbine blade (6) comprises a multi-wall turbine blade (6).

3. The turbine blade cooling system according to any preceding claim, wherein the first turn (60) includes an end wall (62) and the second turn (70) includes an end wall (72), and wherein there is a positional offset of the end wall (62) of the first turn (60) from the end wall (72) of the second turn (70).

4. The turbine blade cooling system according to claim 3, wherein the first turn (60) further includes a side wall (64) having a length equal to the positional offset.

5. The turbine blade cooling system according to any preceding claim, further comprising a rib (80) disposed between the first turn (60) and the second turn (70).

6. The turbine blade cooling system according to any preceding claim, wherein the offset comprises an angular offset.

7. The turbine blade cooling system according to any preceding claim, further comprising a rib (180) disposed at an angle between the first turn (160) and the second turn (170), wherein the rib (180) directs

the first flow of gas in a first direction into the central plenum (44), and wherein the rib (180) directs the second flow of gas in a second, different direction into the central plenum (44).

5

8. The turbine blade cooling system according to any preceding claim, wherein the first turn (160) includes an end wall (162) and the second turn (170) includes an end wall (172), and wherein the end wall (162) of the first turn (160) is substantially coplanar with the end wall (172) of the second turn (170).

10

9. A turbine bucket (2), comprising:

a shank (4);
a blade (6) coupled to the shank (4); and
a cooling system, the cooling system including:

15

a first turn (60, 160) for redirecting a first flow of gas flowing through a first channel (28) of the blade (6) into a central plenum (44) of the blade (6);
a second turn (70, 170) for redirecting a second flow of gas flowing through a second channel (38) of the blade (6) into the central plenum (44) of the blade (6);

20

25

wherein the first turn (60, 160) is offset from the second turn (70, 170) to reduce impingement of the first flow of gas and the second flow of gas in the central plenum (44) of the blade (6), the reduced impingement decreasing pressure loss in the central plenum (44) of the blade (6).

30

10. A turbine bucket (2), comprising:

35

a shank (4);
a multi-wall blade (6) coupled to the shank (4);
and
a cooling system, the cooling system including:

40

a first turn (160) for redirecting a first flow of gas flowing through a first channel into a central plenum (44) of the blade (6);
a second turn (170) for redirecting a second flow of gas flowing through a second channel into the central plenum (44) of the blade (6), the first flow of gas and the second flow of gas combining in the central plenum (44);

45

50

wherein the first turn (160) is angularly offset from the second turn (170) to reduce impingement of the first flow of gas and the second flow of gas in the central plenum (44) of the blade (6), the reduced impingement decreasing pressure loss in the central plenum (44).

55

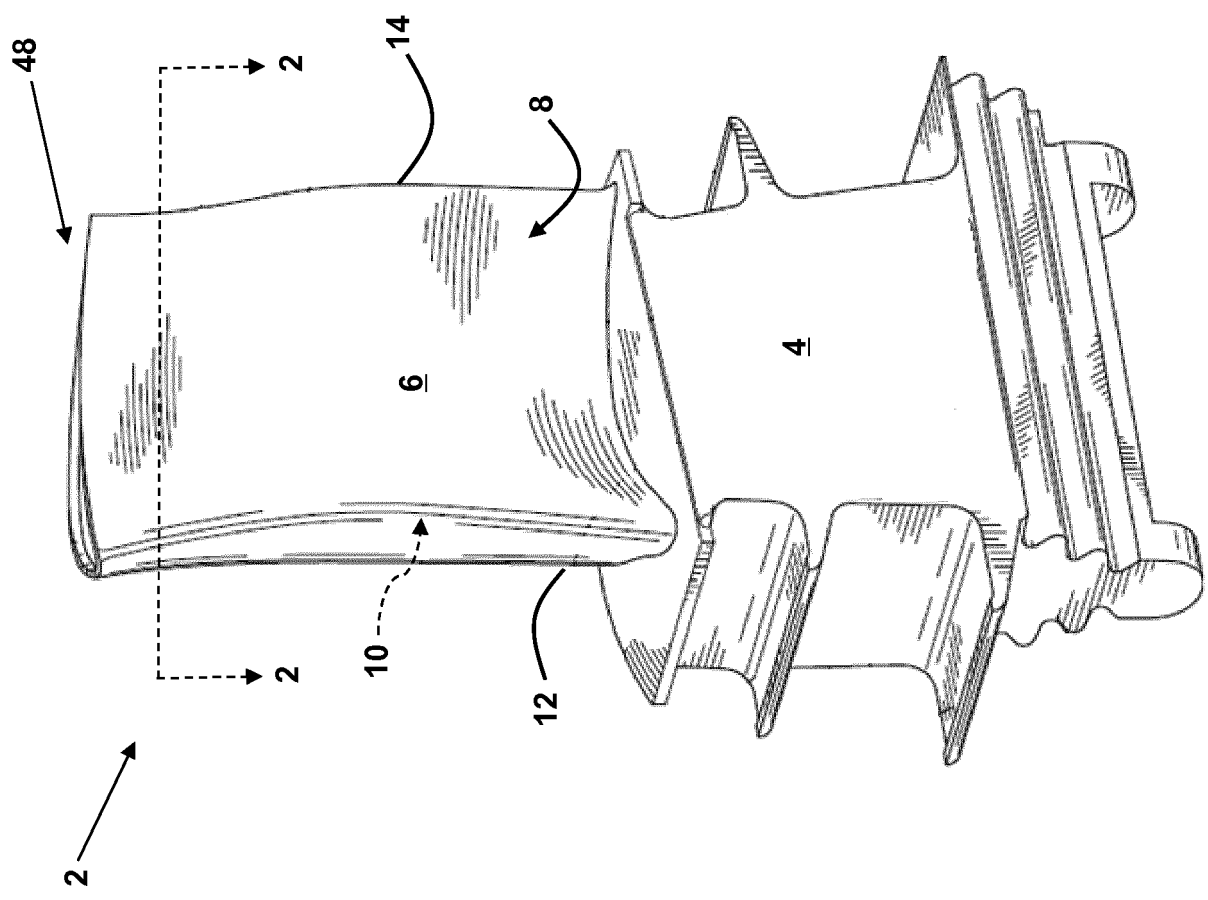


FIG. 1

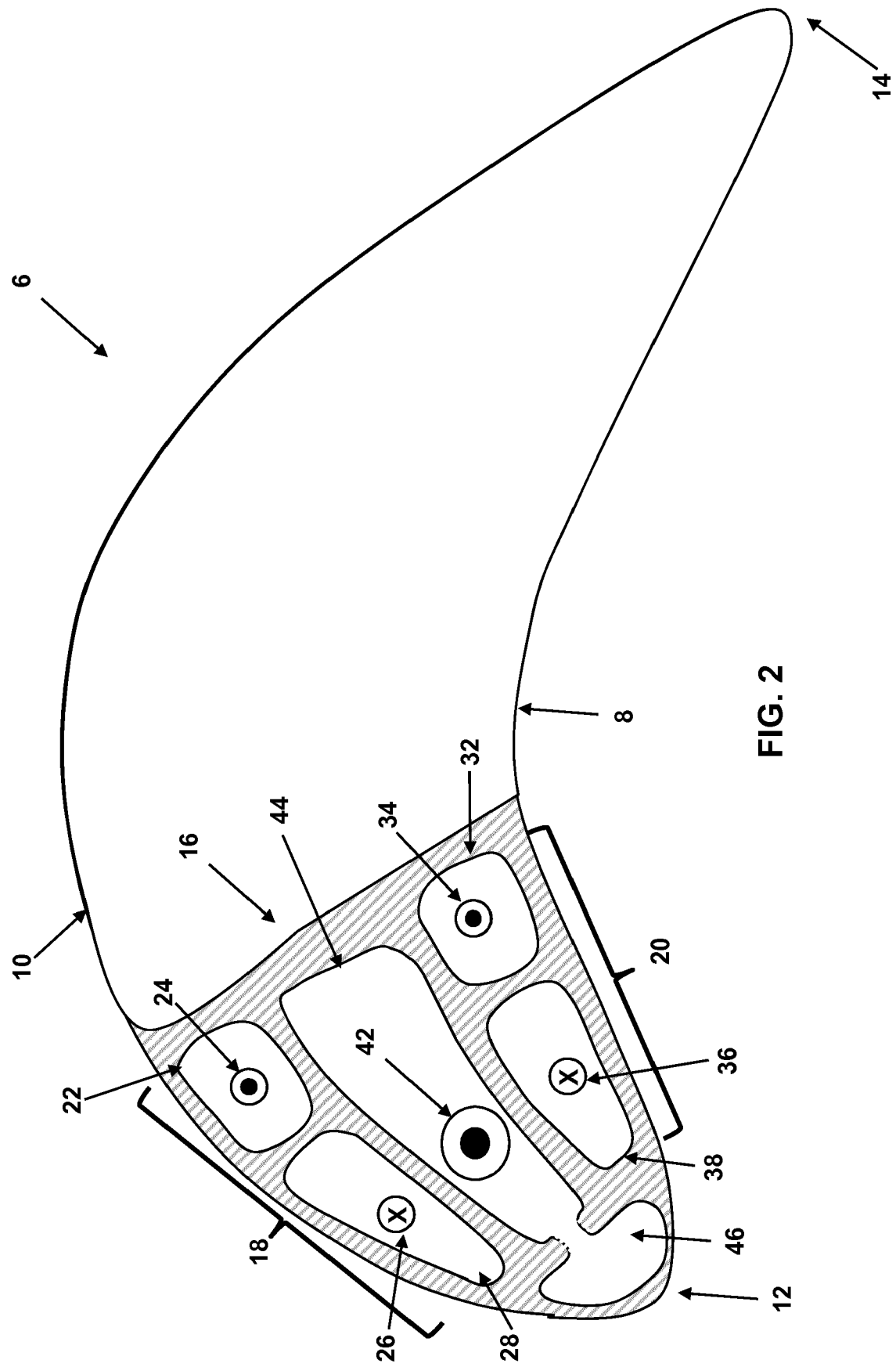


FIG. 2

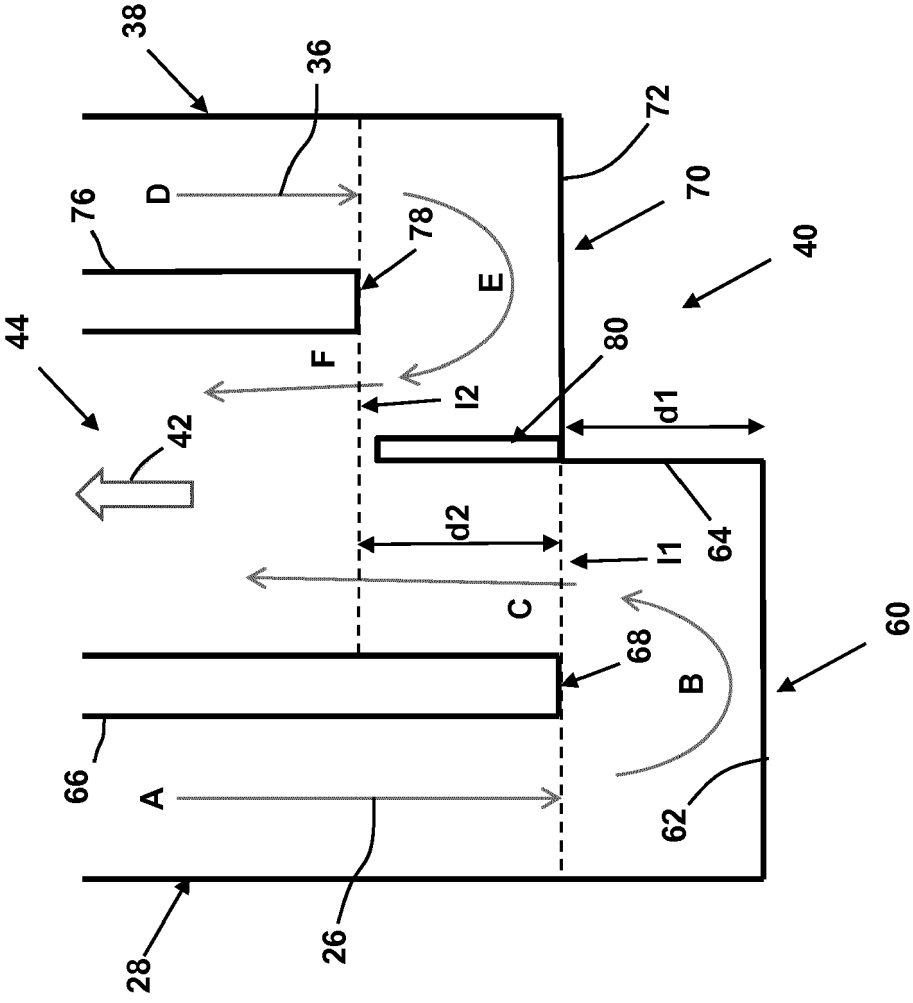


FIG. 3

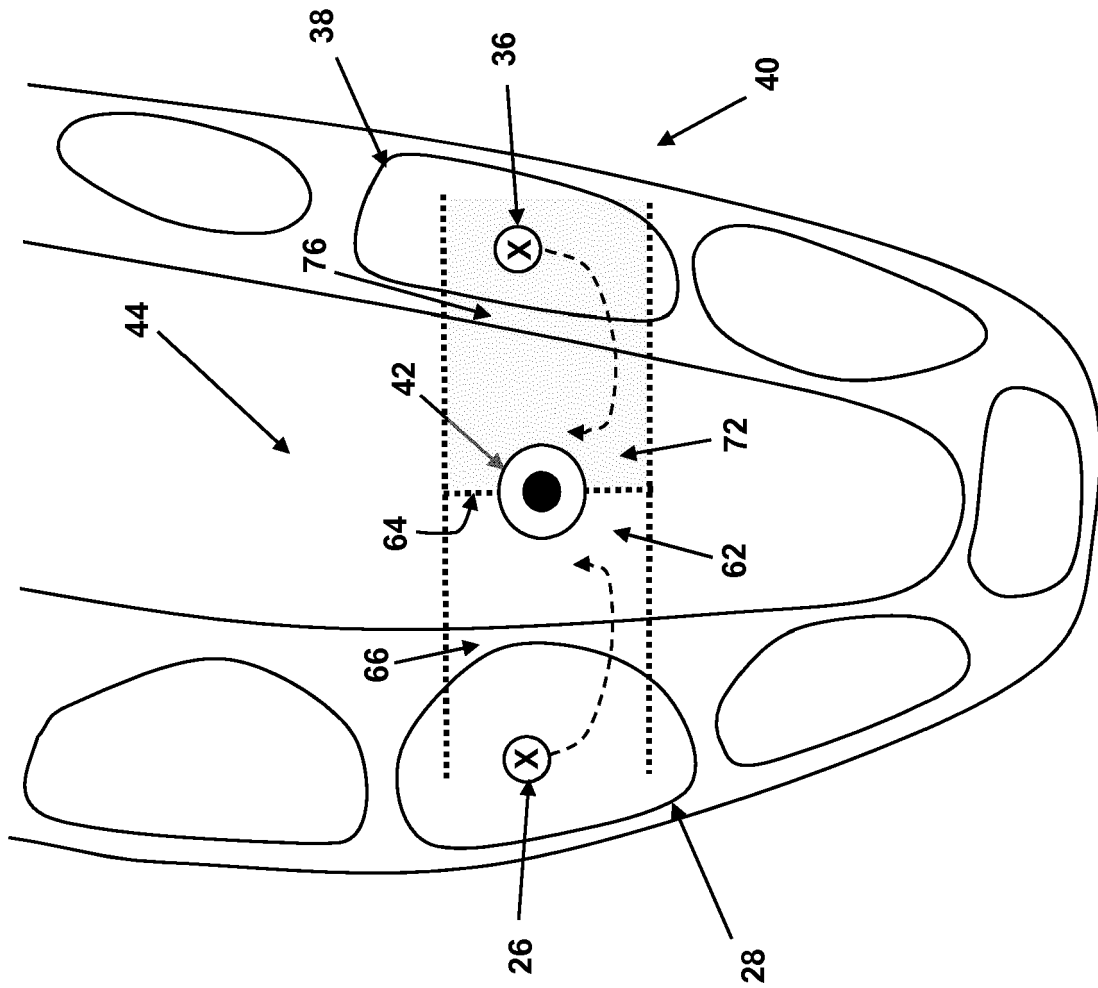


FIG. 4

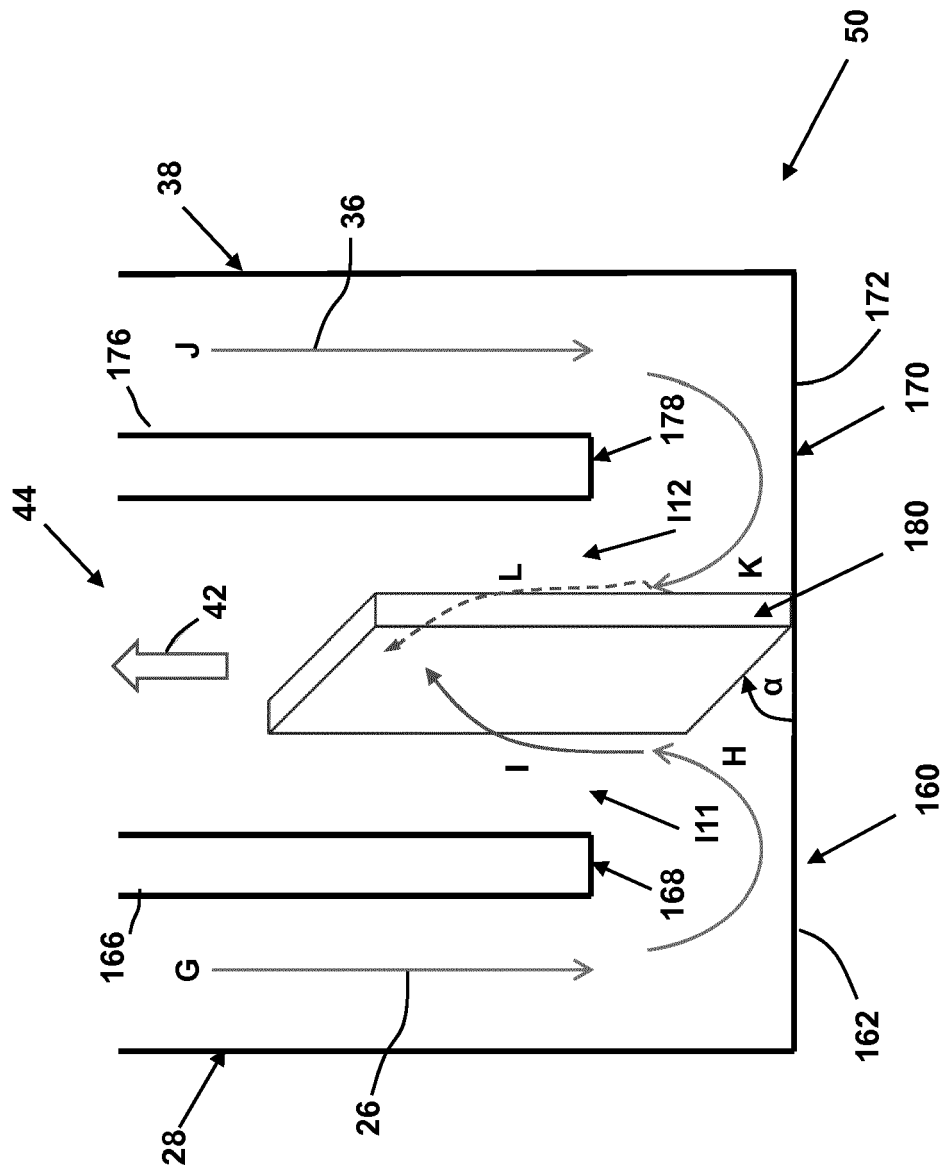


FIG. 5

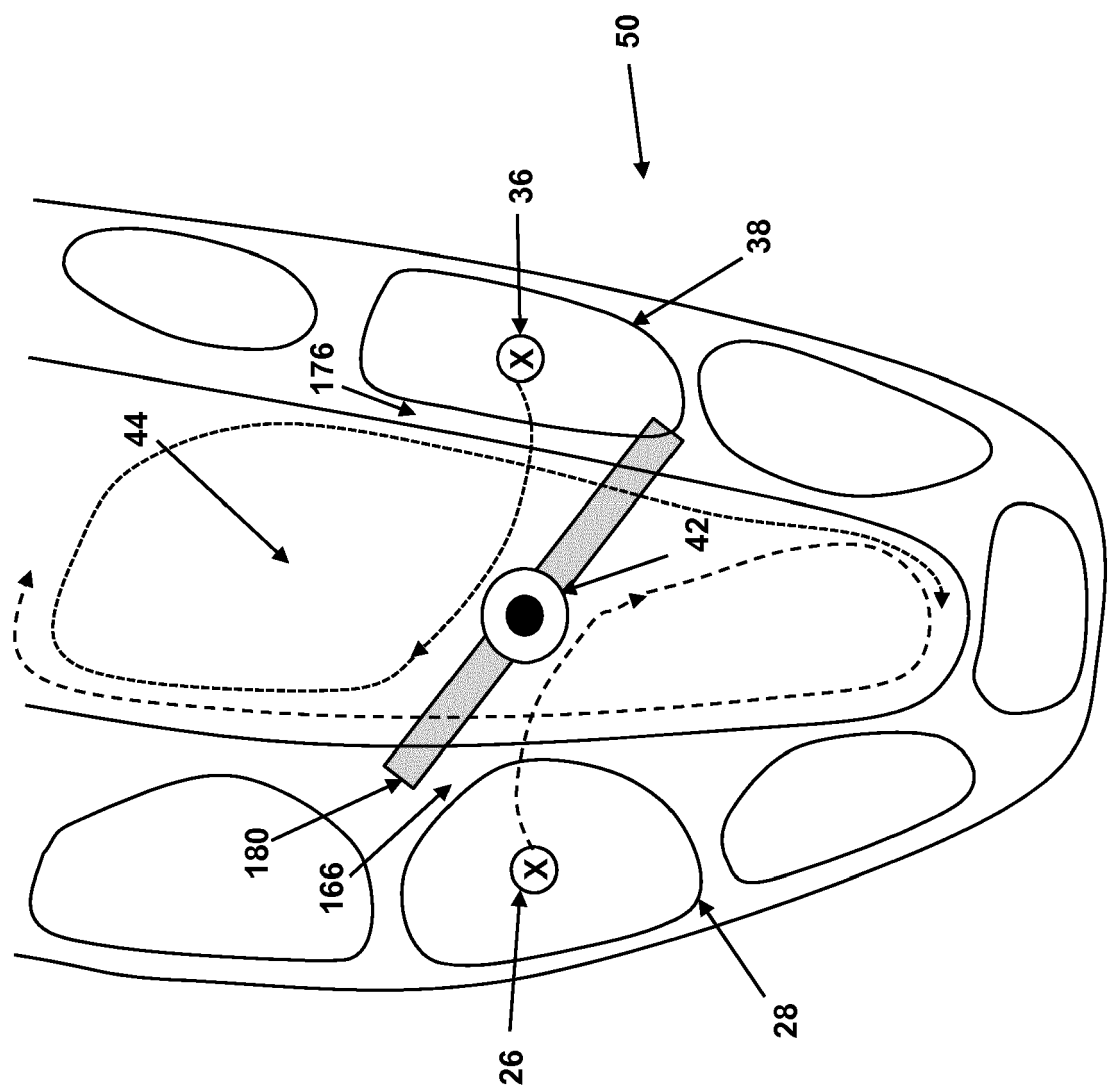


FIG. 6



EUROPEAN SEARCH REPORT

Application Number
EP 16 20 5162

5

10

15

20

25

30

35

40

45

50

55

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2006/153678 A1 (LIANG GEORGE [US]) 13 July 2006 (2006-07-13) * paragraph [0025]; figure 4 *	1-6,9,10	INV. F01D5/18
X	US 2014/286790 A1 (MOLTER STEPHEN MARK [US] ET AL) 25 September 2014 (2014-09-25) * figures 3,7 *	1-6,9,10	
X	JP H09 303103 A (TOSHIBA CORP) 25 November 1997 (1997-11-25) * paragraph [0034]; figures 1,2,4 *	1-3,5,6, 8-10	
A	EP 2 149 676 A1 (ROLLS ROYCE PLC [GB]) 3 February 2010 (2010-02-03) * paragraphs [0049] - [0051]; figures 6,7,8 *	7	
			TECHNICAL FIELDS SEARCHED (IPC)
			F01D
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 25 April 2017	Examiner Teusch, Reinhold
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 16 20 5162

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

25-04-2017

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2006153678 A1	13-07-2006	NONE	
US 2014286790 A1	25-09-2014	CA 2903991 A1 CN 105143608 A EP 2971542 A1 JP 2016511363 A US 2014286790 A1 WO 2014186022 A1	20-11-2014 09-12-2015 20-01-2016 14-04-2016 25-09-2014 20-11-2014
JP H09303103 A	25-11-1997	NONE	
EP 2149676 A1	03-02-2010	EP 2149676 A1 EP 2157282 A1 US 2010124484 A1 US 2010124485 A1	03-02-2010 24-02-2010 20-05-2010 20-05-2010